

LESSON:

Which Graph Is Best?

Summary Students read a short article about electronic waste (e-waste) and review data on e-waste management in the United States. Then they create different types of graphs to present the e-waste data and evaluate which graph type best represents the data.

Lesson Type **Graphic Organization and Modeling**—students organize information graphically (e.g., using figures, graphs, and/or webs).

EHP Article Keeping Apace with e-Waste
Environ Health Perspect 116:A380 (2008)
<http://www.ehponline.org/docs/2008/116-9/forum.html#beat>

Objectives By the end of this lesson, students should be able to

- describe the purpose of graphing data
- differentiate among types of graphs
- list the qualities of a good graph
- formulate principles outlining when it is appropriate to use different types of graphs

Class Time 1 hour

Grade Level Middle school, high school

Subjects Addressed Environmental Science, General Science

► Aligning with Standards

SKILLS USED OR DEVELOPED

- Classification
- Computation
- Critical thinking and response
- Graph reading
- Graphing
- Tables and figures (creating, reading)

SPECIFIC CONTENT ADDRESSED

- Electronic waste
- Use of graphs in presenting data

NATIONAL SCIENCE EDUCATION STANDARDS MET

Science Content Standards

Unifying Concepts and Processes Standard

- Systems, order, and organization
- Evidence, models, and explanation

Science as Inquiry Standard

- Abilities necessary to do scientific inquiry

Science in Personal and Social Perspectives Standard

- Personal and community health
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

History and Nature of Science Standard

- Science as a human endeavor
- Nature of scientific knowledge



► Prepping the Lesson (20 minutes)

INSTRUCTIONS

1. Download the article “Keeping Apace with e-Waste” at <http://www.ehponline.org/docs/2008/116-9/forum.html#beat>.
2. Review the Background Information, Instructions, Assessing the Lesson, and Student Instructions for this lesson. This lesson uses “jigsawing” to divide students into groups. The Implementing the Lesson section provides additional instructions on how to do a jigsaw activity. It may be helpful to have students already divided into their first set of groups before implementing the lesson.
3. Make copies of the Student Instructions and the article.
4. Gather additional materials as needed and decide whether students will be producing their graphs on graph paper or using a computer graphing program.
5. You may wish to look up information on e-waste recycling options in your community in preparation for Step 2c of the Student Instructions.

MATERIALS (per student)

- 1 copy of the article “Keeping Apace with e-Waste,” preferably in color
- 1 copy of the Student Instructions
- 3 sheets of graph paper or access to a computer with a graphing program

VOCABULARY

- bar graph
- column graph
- electronic waste (e-waste)
- line graph
- pie graph

BACKGROUND INFORMATION

Graphs

Graphs are visual representations of data. Scientists use graphs to help simplify and clarify data, and graphs often aid in comparisons among data. Depending on the complexity and technical nature of the data being presented, it can be challenging to choose the graph type that best represents the data. Graphs should be simple and clear in representing the data, so it is important to select the best type of graph for the data. There are several types of graphs:

- **Column graphs (vertical bars):** Column graphs typically have two axes, a horizontal x-axis and a vertical y-axis. The items or categories being compared are usually plotted across the x-axis. The frequency or value of each item or category is usually plotted on the y-axis.
- **Bar graphs (horizontal bars):** Bar graphs are similar to column graphs. Sometimes the terms *bar* and *column* are used interchangeably. For this lesson, bar graphs are the opposite of column graphs; the frequency or value of each item or category is plotted on the x-axis, whereas the items or categories being compared are plotted on the y-axis.
- **Line graphs:** The line graph is among the most popular graphs used to represent data. The independent variable is plotted on the x-axis, and the dependent variable is plotted on the y-axis. Points on the graph are connected by lines.
- **Pie graphs:** Pie graphs are circular charts subdivided into sectors showing the relative proportions of the units of data. The sectors are shown as different-size wedges of a pie.

e-Waste

This lesson is based on a very short *EHP* news article describing the creation of an e-waste action group (Dooley 2008). The more in-depth e-waste data used in the lesson are drawn from an earlier *EHP* research article (Huo 2007) and from a report by the U.S. Environmental Protection Agency (U.S. EPA 2008).

In *Electronics Waste Management in the United States: Approach I* (U.S. EPA 2008), the EPA describes e-waste as being “generated” each year. This refers to the quantity of electronic equipment that reaches the end of its useful life that year.



Obsolete electronics may be either recycled or disposed. Recycled e-waste may be refurbished and resold. It also may be dismantled into constituent parts that are used to make new products, with the remainder sent to a landfill or incinerator. Disposed e-waste generally is discarded in a landfill.

Electronic devices contain many potentially toxic materials, including lead, mercury, cadmium, and brominated flame retardants. This lesson focuses on the lead found in electronics. Lead does not pose a health problem as long as it is contained in electronic equipment. However, when electronic products are put in a landfill or improperly disposed (for instance, dumped in a field somewhere), lead and other metals may leach out of broken equipment and get into drinking water and soil. Lead can affect almost every organ and system in the human body, especially the nervous system, and there is believed to be no threshold of exposure at which some effect does not occur (Centers for Disease Control and Prevention 2007).

Individuals who dismantle electronic equipment during the recycling process can be exposed to lead if proper precautions are not taken to prevent or minimize the exposures (such as wearing appropriate protective gear). A good recycling program should reduce the amount of lead entering the environment.

References

- Centers for Disease Control and Prevention. 2007. Toxicological profile for lead. <http://www.atsdr.cdc.gov/toxprofiles/tp13.pdf>
- Dooley EE. 2008. Keeping apace with e-waste. *Environ Health Perspect* 116:A380. <http://www.ehponline.org/docs/2008/116-9/forum.html#beat>
- Huo X, Peng L, Xu X, Zheng L, Qiu B, Qi Z, Zhang B, Han D, Piao Z. 2007. Elevated blood lead levels of children in Guiyu, an electronic waste recycling town in China. *Environ Health Perspect* 115:1113–1117. <http://www.ehponline.org/members/2007/9697/9697.html>
- U.S. Environmental Protection Agency. 2008. Electronics waste management in the United States: approach I; final. <http://www.epa.gov/osw/conservation/materials/recycling/docs/app-1.pdf>

RESOURCES

- Environmental Health Perspectives*, Environews by Topic page, <http://ehp.niehs.nih.gov/>. Choose Lead, Recycling, Telecommunications/Information Technology
- Partnership for Action on Computing Equipment (PACE) homepage. <http://www.basel.int/industry/compartnership/index.html>
- The Basel Action Network, Silicon Valley Toxics Coalition. 2002. Exporting harm: the high-tech trashing of Asia. <http://ban.org/E-waste/technotrashfinalcomp.pdf>
- Computer Takeback Campaign, Californians Against Waste. 2004. Poison PCs and toxic TVs. <http://svtc.igc.org/cleancc/pubs/ppcttv2004.pdf>
- Greenpeace. 2005. Recycling of electronic wastes in China and India: workplace and environmental contamination. <http://www.greenpeace.org/china/en/press/reports/recycling-of-electronic-wastes>

► Implementing the Lesson

INSTRUCTIONS

1. Have students read the article “Keeping Apace with e-Waste” on their own or as a class. Address any questions or clarify terminology as needed.
2. Have students complete Steps 2 and 3 of the Student Instructions and briefly discuss their responses as a class. If necessary, refer to the Background Information section for definitions of *generated*, *disposed*, and *recycled* as those terms are used in this lesson.
3. Tell the students they will be completing this lesson in two phases (a jigsaw activity). In Phase 1, students will be divided into four “Type of Graph” groups. Each group will become experts in one type of graph. Then in Phase 2, students will be re-divided into four “Graph Discussion” groups such that each group includes at least one expert on each type of graph. Depending on the number of students in your class, you may need to have more than one set of groups.

See the chart on the next page for guidance in dividing and re-dividing students into jigsaw groups.



How to Divide Jigsaw Groups			
Phase 1: "Type of Graph" groups (each letter represents one student)			
Column Graph AAAA	Bar Graph BBBB	Line Graph CCCC	Pie Graph DDDD
Phase 2: "Graph Discussion" groups (each letter represents one student)			
ABCD	ABCD	ABCD	ABCD

- Once the students have been divided into "Type of Graph" groups, distribute graph paper or assign computers. Have the groups complete Steps 4 and 5 of the Student Instructions.
- Re-divide students into "Graph Discussion" groups and have them complete Steps 6 through 8 of the Student Instructions. Have each group present its decision on which type of graph and which type of numerical presentation (numbers or percentages) best represent the e-waste data.
- Have students complete Steps 9 through 11 on their own. Discuss their responses as a class. Be prepared to discuss the types of graphs and how they are used with students who have less experience with graphs.

Notes & Helpful Hints

- As an extension of this activity, students might investigate how e-waste is managed by your school district and/or local community.

► Assessing the Lesson (steps not requiring teacher feedback are not listed below; see Student Instructions for complete step-by-step instructions)

Step 3 List one reason why the e-waste data below would be easier to review if the data were presented in a graph.

2007 e-Waste Management in the United States ¹			
Equipment Type	Generated (millions of units)	Disposed (millions of units)	Recycled (millions of units)
Televisions	26.9	20.6	6.3
Computer Products ²	205.5	157.3	48.2
Cell Phones	140.3	126.3	14.0
Total	372.7	304.2	68.5

¹Adapted from U.S. Environmental Protection Agency. 2008. Electronics waste management in the United States: approach I; final.

²Computer products include CPUs, monitors, notebooks, keyboards, mice, and peripherals.

Answers will vary, but look for logical responses. Responses may include:

- Using graphs improves the presentation of the data.
- Graphs make it easier to interpret or compare data.
- Graphs can help to simplify complex sets of data.

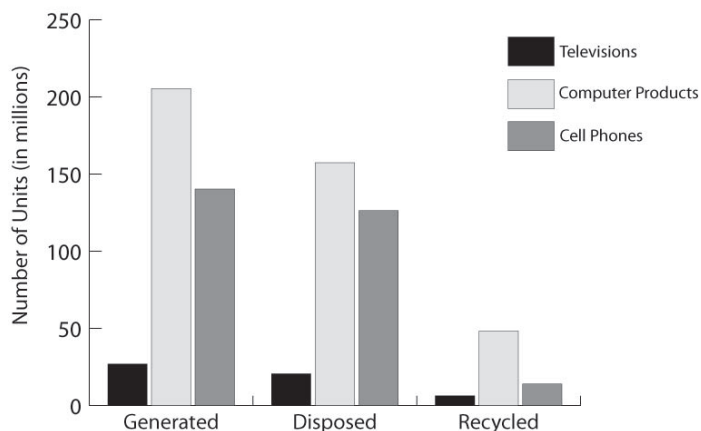
Step 4 Now you will divide into "Type of Graph" groups as directed by your teacher [Teacher note: This is Phase 1 of the jigsaw activity]. Each group will be assigned one type of graph: column graphs, bar graphs, line graphs, or pie graphs. Each group member will create three graphs of the data in Step 3 using the type of graph assigned to your group (each member of the Pie Graph group will create two sets of three graphs). For each graph, be sure to provide a title and a legend, label the axes, and specify the units of measurement.

Graphs for each group are shown on the pages that follow.

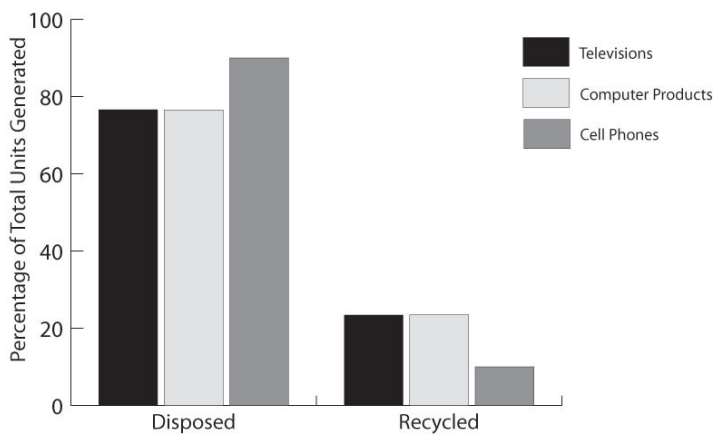


Column Graph group

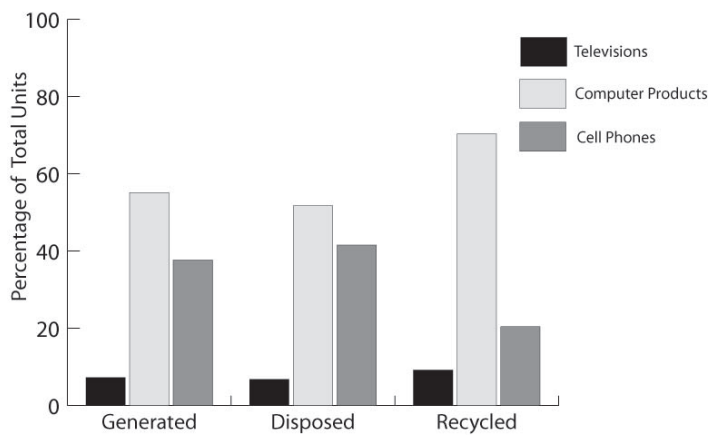
a. 2007 Electronic Waste Management in the United States
By Actual Number of Units (in millions)



b. 2007 Electronic Waste Management in the United States
By Percentage of Total Units Generated

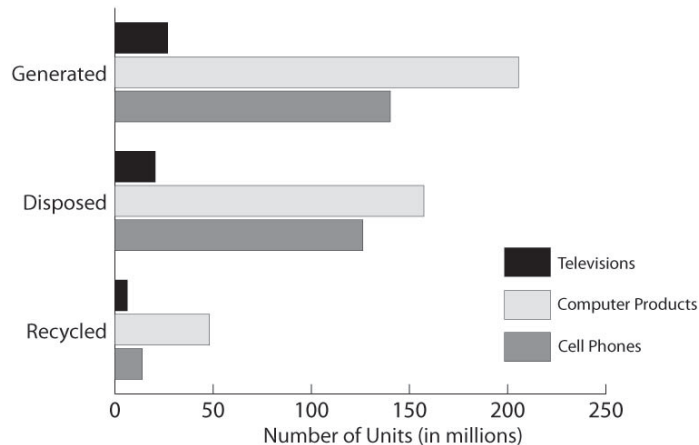


c. 2007 Electronic Waste Management in the United States
By Percentage of Total Units

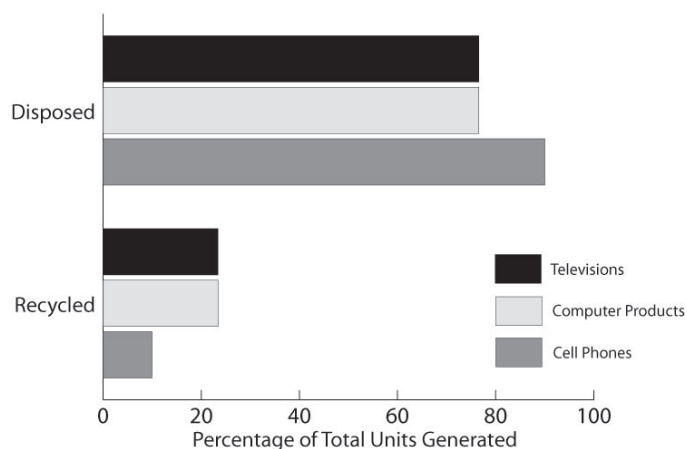


Bar Graph group

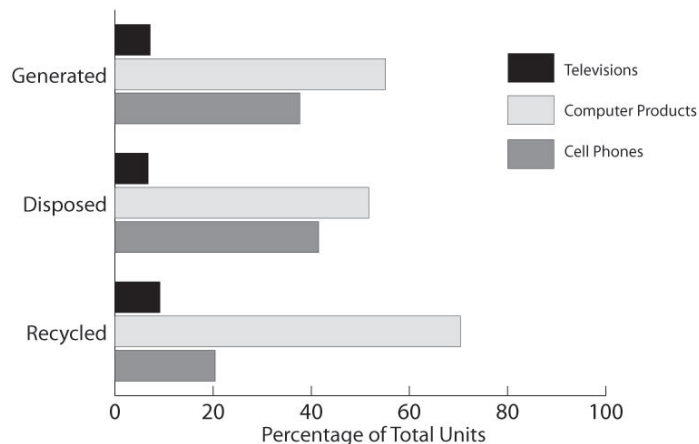
a. 2007 Electronic Waste Management in the United States
By Actual Number of Units (in millions)



b. 2007 Electronic Waste Management in the United States
by Percentage of Total Units Generated

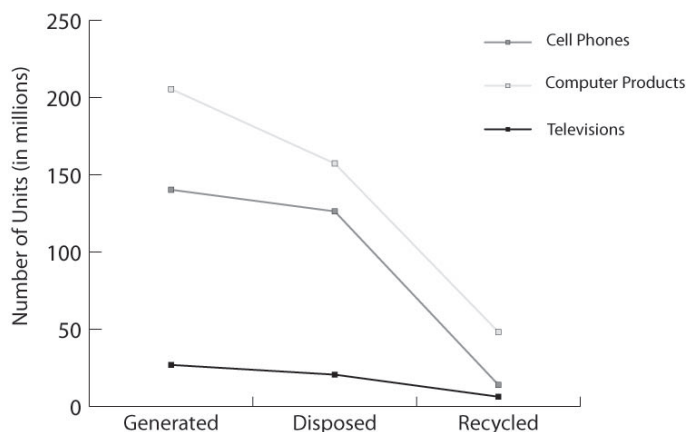


c. 2007 Electronic Waste Management in the United States
by Percentage of Total Units

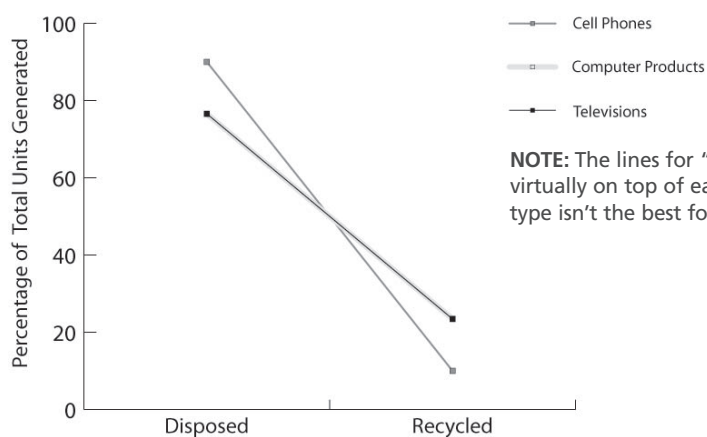


Line Graph group

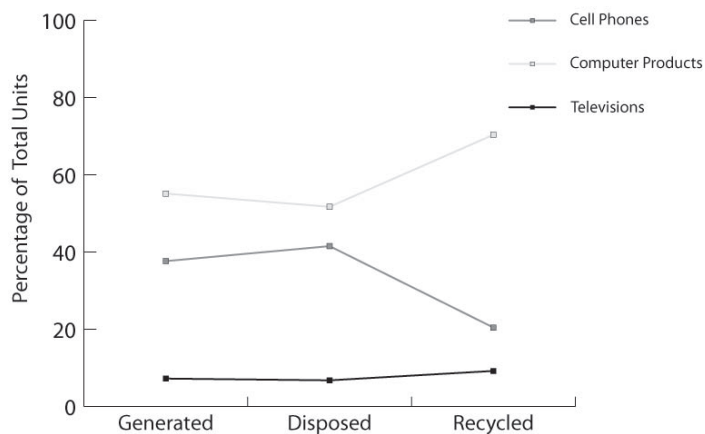
a. 2007 Electronic Waste Management in the United States
By Actual Number of Units (in millions)



b. 2007 Electronic Waste Management in the United States
By Percentage of Total Units Generated



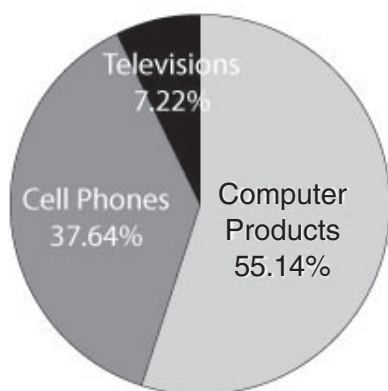
c. 2007 Electronic Waste Management in the United States
By Percentage of Total Units



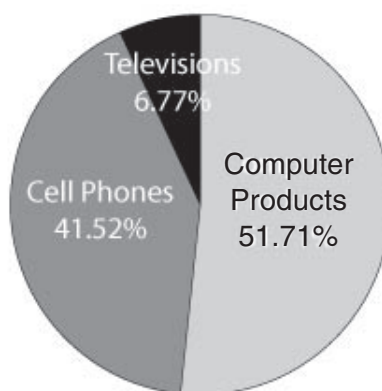
Pie Graph group

a.

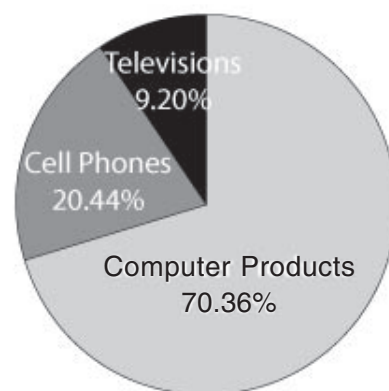
2007 Electronic Waste Management in the United States by Electronic Waste Management Process



Generated



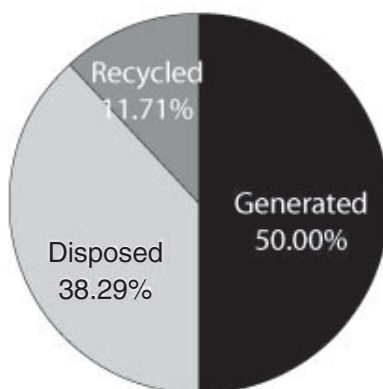
Disposed



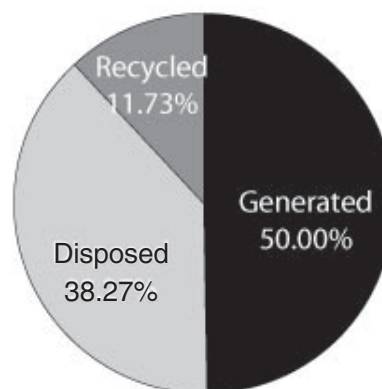
Recycled

b.

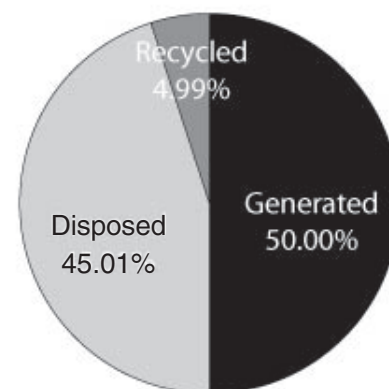
2007 Electronic Waste Management in the United States by Type of Electronic Equipment



Televisions



Computer Products



Cell Phones



Step 5 a. Are the e-waste data you graphed represented well using this type of graph? Why or why not?

Answers will vary depending on the type of graph used to represent the data and students' own assessments; look for logical responses. Here are some rules of thumb about the appropriate use of each type of graph:

Column graphs (vertical bars)

- Best used for comparing multiple categories when a time-based scale is needed.
- Good for showing changes over time, with time depicted on the x-axis.

Bar graphs (horizontal bars)

- Best used for comparing multiple categories, but not when a time-based scale is needed.
- Particularly useful when category labels are long.

Line graphs

- Best used for showing relationships among data points over time.
- Lines show peaks and dips in the data, making comparisons easy to see.

Pie graphs

- Best for showing parts (percentages) of the whole.
- Tip for ease of use: lay out largest portions first, then lay out successively smaller portions in a clockwise manner.

b. Are the data better represented by actual numbers or by percentages?

Answers may vary; look for logical responses.

Step 7 a. Which types of graphs are easiest to understand for the data presented in this activity? Why do you think so?

Answers may vary; look for logical responses.

b. Which types of graphs are the most confusing or difficult to understand for the data presented in this activity? Why do you think so?

Answers may vary; look for logical responses. Line graphs and pie graphs should be mentioned as types of graphs that do not represent these data particularly well.

c. Discuss when each type of graph should be used. Outline at least two principles for using each type of graph. For example, should the type of graph be used for comparing categories? Should it be used to show changes over time? Should it be used to show changes in amounts?

Refer to possible answers for Step 5a.

Step 8 Decide which type of graph best represents the e-waste data presented in this activity and whether numbers or percentages should be used. Why do you think so? Be prepared to present your group's decision and reasons to the class.

Answers will vary depending on students' assessment of the best type of graph for the e-waste data; look for logical responses. Students should be able to identify that it is easier to identify potential priority areas when looking at the raw numbers; for instance, although a higher percentage of computer products are recycled compared with the other product types, the number of computer product units disposed is still very high, higher than for cell phones and televisions.



Step 9 On average, a television set and a computer monitor both contain 4 to 8 pounds of lead (cell phones also contain lead, but a much smaller amount; for the next two steps we will consider only televisions and computer products). Look back at the data in Step 3. Assuming an average of 6 pounds per unit for televisions and 4 pounds per unit for computer products (because the computer products category includes additional equipment that may not contain lead), calculate the total amount of lead contained in the televisions and computer products that were disposed and recycled in 2007. Create a table detailing this information. Be sure to include a title and labels on your table. Also, don't forget to convert the number of units to millions.

Approximate Amount of Lead Contained in e-Waste Per Year (2007)		
Equipment Type	Amount in Disposed e-Waste (in pounds)	Amount in Recycled e-Waste (in pounds)
Televisions	123,600,000	37,800,000
Computer Products	629,200,000	192,800,000
Total	752,800,000	230,600,000

Step 10 Very large numbers can sometimes be difficult to conceptualize, so data are often presented in different ways to increase the public's understanding of the scope of an issue. In Step 9 you calculated the total amount of lead in the e-waste that was disposed and recycled in 2007. Now calculate the average amount of lead in e-waste that was disposed and recycled *each day* in 2007.

Approximate Amount of Lead Contained in e-Waste Per Day (2007)		
Equipment Type	Amount in Disposed e-Waste (in pounds)	Amount in Recycled e-Waste (in pounds)
Televisions	338,630.1	103,561.6
Computer Products	1,723,835.6	528,219.2
Total	2,062,465.7	631,780.8

Step 11 One of the goals of the Partnership for Action on Computing Equipment (PACE), mentioned in the *EHP* article, is to increase awareness about e-waste. Suppose PACE asked you to help them increase public awareness about the safe recycling of e-waste. What three main points from this lesson would you want to convey to the public? Which graph type(s) might you use to illustrate your points?

Answers will vary depending on students' assessment of which points are most important and which graph represents the data best, but look for logical responses. Examples of main points might include:

- Cell phones are the least recycled type of e-waste.
- Although far more computer products are generated than televisions, both types of e-waste appear to be recycled at a similar rate. However, when looking at the total units disposed, there are still many more computer product units disposed than there are cell phones or televisions.
- Overall only 18% of e-waste is recycled.
- Once students look at the amount of lead present in computer products (Steps 9 and 10), these data together with the percentage and units disposed, indicate that the most time, energy, and money should probably be put into recycling computer products, compared with the other products. Students may also indicate that to make a well-informed decision, they should compare the amounts of other toxic chemicals in the products



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Give us your feedback! Send comments about this lesson to ehpscienceed@niehs.nih.gov.





STUDENT INSTRUCTIONS: Which Graph Is Best?

Step 1 Read the article “Keeping Apace with e-Waste.”

Step 2 As a class discuss the following questions about electronic waste (or e-waste).

- Have you or your family gotten rid of a television, computer (desktop or laptop), or cell phone within the last year? If so, how many?
- If you answered yes, how did you dispose of the equipment? Did you recycle it? Where?
- Do you know where to go to recycle e-waste in your community? Is it easy to recycle e-waste where you live? Why or why not?

Step 3 Management of e-waste is an emerging global environmental issue. Although e-waste represents a small percentage of the total municipal solid waste stream, it is the portion growing the most rapidly, having more than doubled in a decade, according to the U.S. Environmental Protection Agency. The table below shows data about the management of e-waste in the United States. Review the data and think about how these figures might be represented graphically. List one reason why the e-waste data below would be easier to review if the data were presented in a graph.

2007 e-Waste Management in the United States ¹			
Equipment Type	Generated (millions of units)	Disposed (millions of units)	Recycled (millions of units)
Televisions	26.9	20.6	6.3
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¹Adapted from U.S. Environmental Protection Agency. 2008. Electronics waste management in the United States: approach I; final.

²Computer products include CPUs, monitors, notebooks, keyboards, mice, and peripherals.

Step 4 Now you will divide into “Type of Graph” groups as directed by your teacher. Each group will be assigned one type of graph: column graphs, bar graphs, line graphs, or pie graphs. Each group member will create three graphs of the data in Step 3 using the type of graph assigned to your group (each member of the Pie Graph group will create two sets of three graphs). For each graph, be sure to provide a title and a legend, label the axes, and specify the units of measurement.



Instructions for Column Graph, Bar Graph, and Line Graph groups (Pie Graph group go to page 3)

Column Graph group: Plot the numbers or percentages of units on the y-axis and the e-waste management processes (generated, disposed, recycled) on the x-axis.

Bar Graph group: Plot the e-waste management processes (generated, disposed, recycled) on the y-axis and the numbers or percentages of units on the x-axis.

Line Graph group: Plot the numbers or percentages of units on the y-axis and the e-waste management processes (generated, disposed, recycled) on the x-axis.

- a. Graph 1: Using the data from Step 3, plot the actual number of units included in each e-waste management process (generated, disposed, recycled).
- b. Graph 2: Calculate the percentage of each equipment type (televisions, computer products, cell phones) that was disposed and the percentage that was recycled by dividing the number of units disposed and the number of units recycled by the number of units generated. See the sample calculation that has already been filled in for televisions; 23.4% of all televisions generated were recycled. Then plot the percentage of units disposed and recycled as a function of equipment type. Hint: This graph will have only two categories.

Equipment Type	Percentage Disposed	Percentage Recycled
Televisions		$6.3 / 26.9 = 23.4\%$
Computer Products		
Cell Phones		

- c. Graph 3: Calculate the percentage that each equipment type (televisions, computer products, cell phones) makes up of each e-waste management process (generated, disposed, recycled) by dividing the number of units of each equipment type by the total number of units for each e-waste management process. See the sample calculation that has already been filled in for televisions; televisions make up 7.2% of total generated e-waste. Then plot the percentage of each equipment type as a function of e-waste management process.

Equipment Type	Percentage of Total Generated Units	Percentage of Total Disposed Units	Percentage of Total Recycled Units
Televisions	$26.9 / 372.7 = 7.2\%$		
Computer Products			
Cell Phones			



Instructions for Pie Graph group

- a. First set of three graphs: Using the data from Step 3, calculate the percentage that each equipment type (televisions, computer products, cell phones) makes up of each e-waste management process (generated, disposed, recycled) by dividing the number of units of each equipment type by the total number of units for each e-waste management process. See the sample calculation that has been filled in for televisions; televisions make up 7.2% of total generated e-waste. Then plot the percentage of each equipment type as a function of the e-waste management process.

Equipment Type	Percentage of Total Generated Units	Percentage of Total Disposed Units	Percentage of Total Recycled Units
Televisions	$26.9 / 372.7 = 7.2\%$		
Computer Products			
Cell Phones			

- b. Second set of three graphs: Calculate the percentage that each e-waste management process (generated, disposed, recycled) makes up for each equipment type (televisions, computer products, cell phones) by dividing the number of units for each e-waste management process by the total number of units for each equipment type. See the sample answer already filled in for percentage of televisions that are disposed. Then plot the percentage of each e-waste management process as a function of equipment type. Hint: you will need to add up the three processes for each equipment type.

Equipment Type	Percentage Generated	Percentage Disposed	Percentage Recycled
Televisions		$20.6 / 53.8 = 38.3\%$	
Computer Products			
Cell Phones			



- Step 5** Discuss the type of graph assigned to your group by your teacher.
- Are the e-waste data you graphed represented well using this type of graph? Why or why not?
 - Are the data better represented by actual numbers or by percentages?
- Step 6** Now you will re-divide into “Graph Discussion” groups as directed by your teacher. Present your three graphs to the other members of your group. Discuss the graphs as needed to understand what they say. If anything is unclear or confusing in the graphs, make a note of it.
- Step 7** A good graph provides a clear and accurate representation of data that can be interpreted quickly by the reader. The best graphs are both simple and uncluttered. Review all the types of graphs and answer the following questions.
- Which types of graphs are the easiest to understand for the data presented in this activity? Why do you think so?
 - Which types of graphs are the most confusing or difficult to understand for the data presented in this activity? Why do you think so?



- c. Discuss when each type of graph should be used. Outline at least two principles for using each type of graph. For example, should the type of graph be used for comparing categories? Should it be used to show changes over time? Should it be used to show changes in amounts?
- Column graph (vertical bars)

 - Bar graph (horizontal bars)

 - Line graph

 - Pie graph

Step 8 Decide which type of graph best represents the e-waste data presented in this activity and whether numbers or percentages should be used. Why do you think so? Be prepared to present your group's decision and reasons to the class.



Step 9 On average, a television set and a computer monitor both contain 4 to 8 pounds of lead (cell phones also contain lead, but a much smaller amount; for the next two steps we will consider only televisions and computer products). Look back at the data in Step 3. Assuming an average of 6 pounds per unit for televisions and 4 pounds per unit for computer products (because the computer products category includes additional equipment that may not contain lead), calculate the total amount of lead contained in the televisions and computer products that were disposed and recycled in 2007. Create a table detailing this information. Be sure to include a title and labels on your table. Also, don't forget to convert the number of units to millions.

Step 10 Very large numbers can sometimes be difficult to conceptualize, so data are often presented in different ways to increase the public's understanding of the scope of an issue. In Step 9 you calculated the total amount of lead in the e-waste that was disposed and recycled in 2007. Now calculate the average amount of lead in e-waste that was disposed and recycled *each day* in 2007.



- Step 11** One of the goals of the Partnership for Action on Computing Equipment (PACE), mentioned in the *EHP* article, is to increase awareness about e-waste. Suppose PACE asked you to help them increase public awareness about the safe recycling of e-waste. What three main points from this lesson would you want to convey to the public? Which graph type(s) might you use to illustrate your points?

